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OFFICE NOTE 253

Evaluation of the Effect of VAS Data on Some NMC Analyses and Forecasts

Edward A. O'Lenic
Development Division

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Introduction

Since early in 1981, VAS (VISSR Atmospheric Sounder (Visible/ Infrared Spin Scan Radiometer)) data have been under study at the National Meteorological Center (NMC), an arrangement begun by Drs. J. Brown, and W. Smith. This paper presents the results of an experiment conducted between October 1981 and January 1982, designed to examine the effect of VAS data on the Limited-area Fine-mesh model (LFM) analysis-forecast system. The VAS data, taken from the Pacific geostationary satellite would be especially valuable for the LFM analysis because temperatures from the polar-orbiting satellite over the east Pacific are received too late for the 1200 GMT LFM analysis. Because the VISSR has only infrared channels, retrievals are possible only in regions of little or no cloudiness.

A preliminary evaluation using two cases in April 1981 indicated (O'Lenic, 1981;Jones, 1981):

1) VAS data exhibited a small cold bias with respect to NMC analyses below about 300 mb,
2) the data did produce a measurable increase in the amplitude of major features in the LFM height analyses, though
3) the effect of the VAS-wrought change in the LFM analyses upon forecasts subsequently made from these analyses could not be classified as either "positive" , or "negative".

Six cases were chosen at random for the current evaluation, by requiring that, barring computer problems, each case would fall on Tuesday of each week, beginning in November 1981. Each set of VAS observations consisted of about fifty to one hundred mandatory level soundings made in the dwell sounding (DS) mode (Smith et al., 1981; Smith *et al.*, 1981). The soundings, produced at the Cooperative Institute for Meteorological Satellite Studies (CIMSS), Madison, Wisconsin, used the LFM twelve-hour forecast (FM12) valid at the time of the data for a first guess in processing the VAS radiances. CIMSS routinely uses the FM12 1000-mb height field as the reference level from which to build mandatory level soundings from the radiance-derived thicknesses.

The corresponding FM12 1000-mb temperatures serve as the 1000-mb temperatures over water in the CIMMS-VAS soundings. At NMC the 1000-mb first-guess heights were first subtracted from each CIMMS-VAS sounding at all levels in these tests. During the subsequent analysis process, the thicknesses thus derived were added to the 1000-mb height analysis for that case. This analysis also included all routinely available conventional data. In this way, the VAS soundings used in the analysis are built-up from the current 1000-mb analysis which, along with the 300-mb analysis, is performed as the first step of the LFM analysis scheme. These analyses are herein referred to as "VAS" analyses. Analyses using only the available conventional data are referred to as "NOVAS" analyses. Likewise, forecasts prepared from these analyses are called "VAS" and "NOVAS" forecasts, respectively.

In section 2, VAS and NOVAS analyses are compared visually and statistically. VAS-NOVAS analysis differences are also compared with those made for a single case using data from the NOAA-7 polar orbiter. Section 3 discusses forecast error maps for VAS forecasts.

2. VAS versus NOVAS LFM analyses

A series of parallel analyses was prepared in which the only difference between VAS and NOVAS analyses was the addition of VAS data. Further, the 1000-mb analyses in any given pair of VAS/NOVAS analyses were identical.

The full set of VAS analyses, with the VAS observations over-plotted, for the 500-mb level are shown in Figures 1-3. These are provided to familiarize the reader not only with the location and number of the VAS observations, but also, to permit comparison with the set of GOES-West satellite images for these cases, shown in Figures 4-6. Though a long wavelength ridge appears at 500-mb in four of the six cases, Figures 1-6 show that these six cases contain a wide variety of weather phenomena to the west of the California coast: a rapidly developing short wavelength feature races toward the long wavelength ridge in Case A; a strong zonal flow with few perturbations in Case B; a slow-moving cutoff longwave trough (Case C); a highly perturbed zonal flow, with a short wavelength feature coming ashore (Case D); another small-scale feature approaches the coast in Case E; a very high amplitude, very long wavelength flow pattern,which led to be a very unsatisfactory forecast, in Case F.

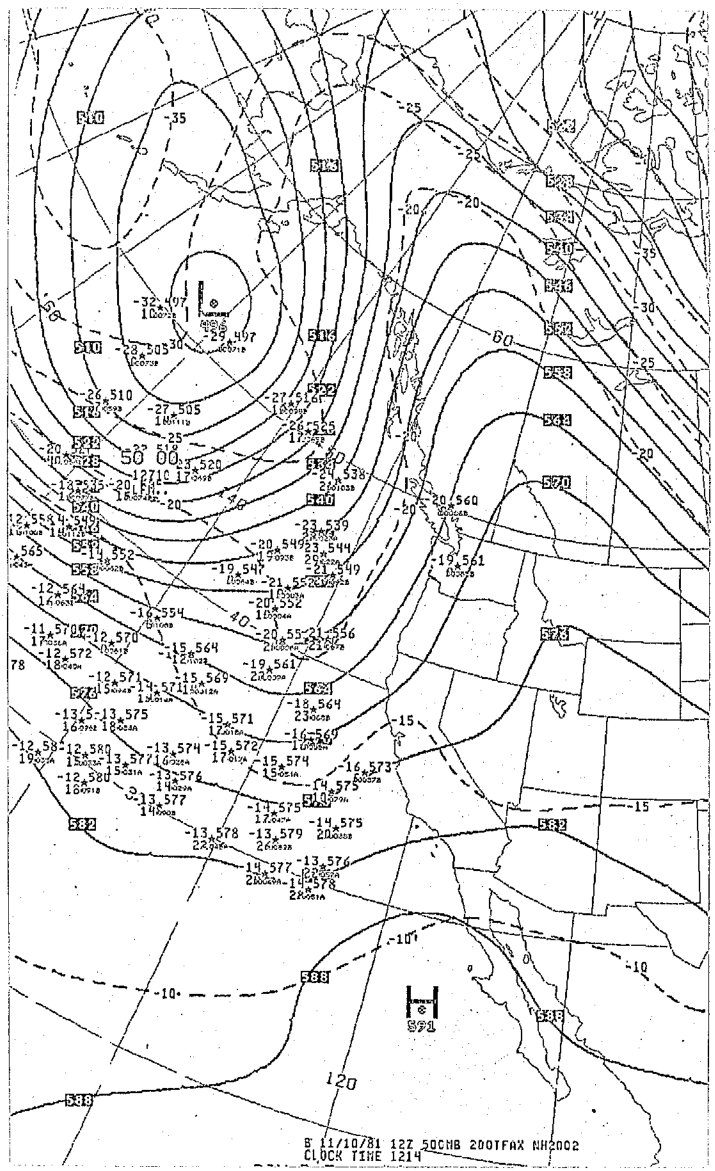


Figure 1A. 11-10-81, 12 GMT LFM 500-mb analysis with VAS data, VAS data over-plotted.

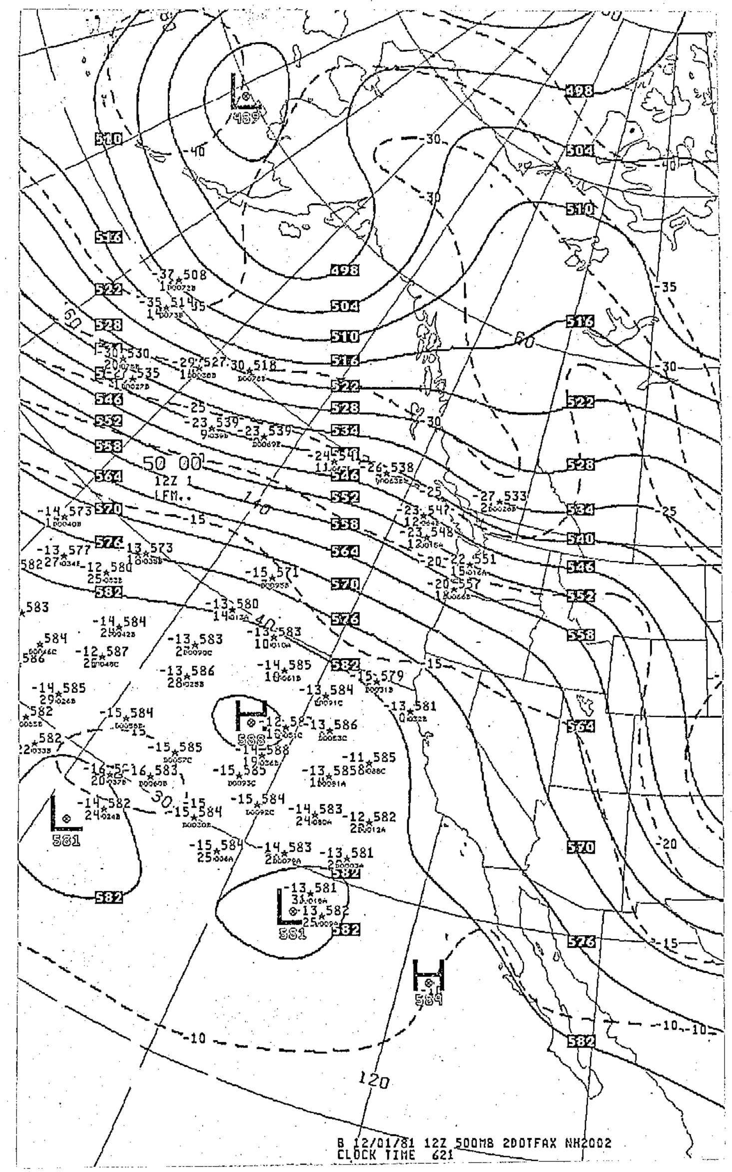


Figure 1B. 12-01-81, 12 GMT LFM 500-mb analysis with VAS data, VAS data over-plotted.

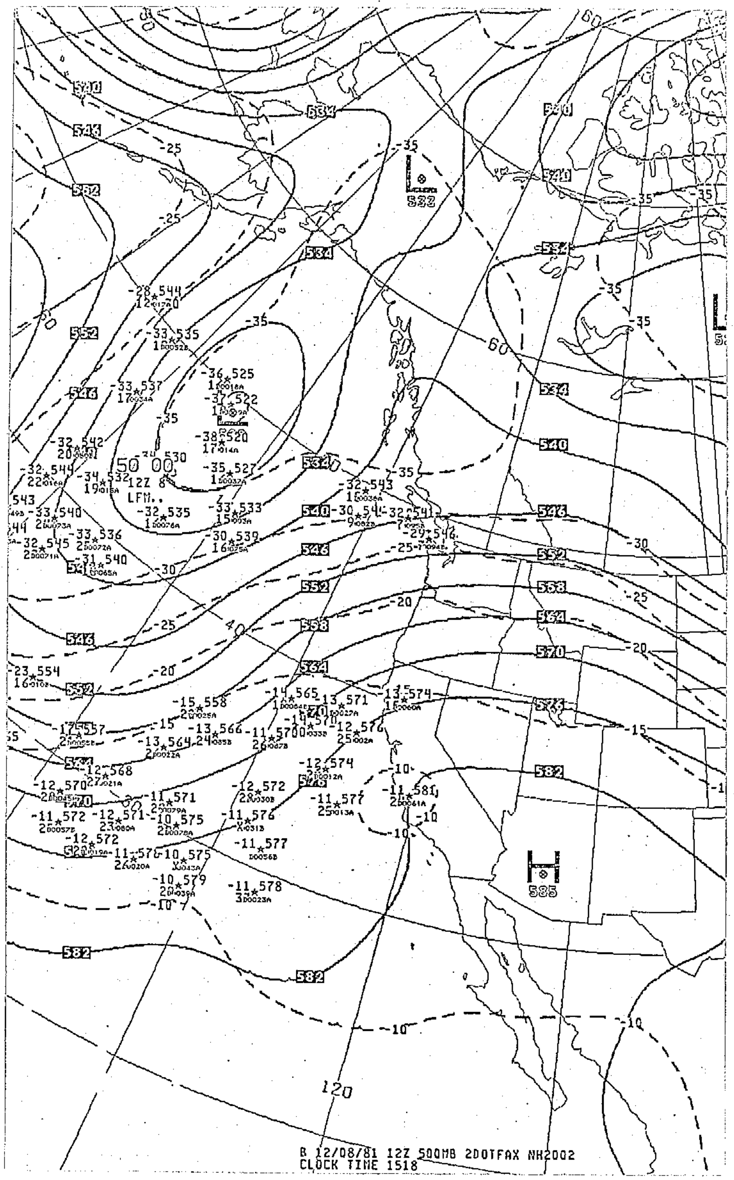


Figure 2A. 12-08-81, 12 GMT LFM 500-mb analysis with VAS data, VAS data over-plotted.

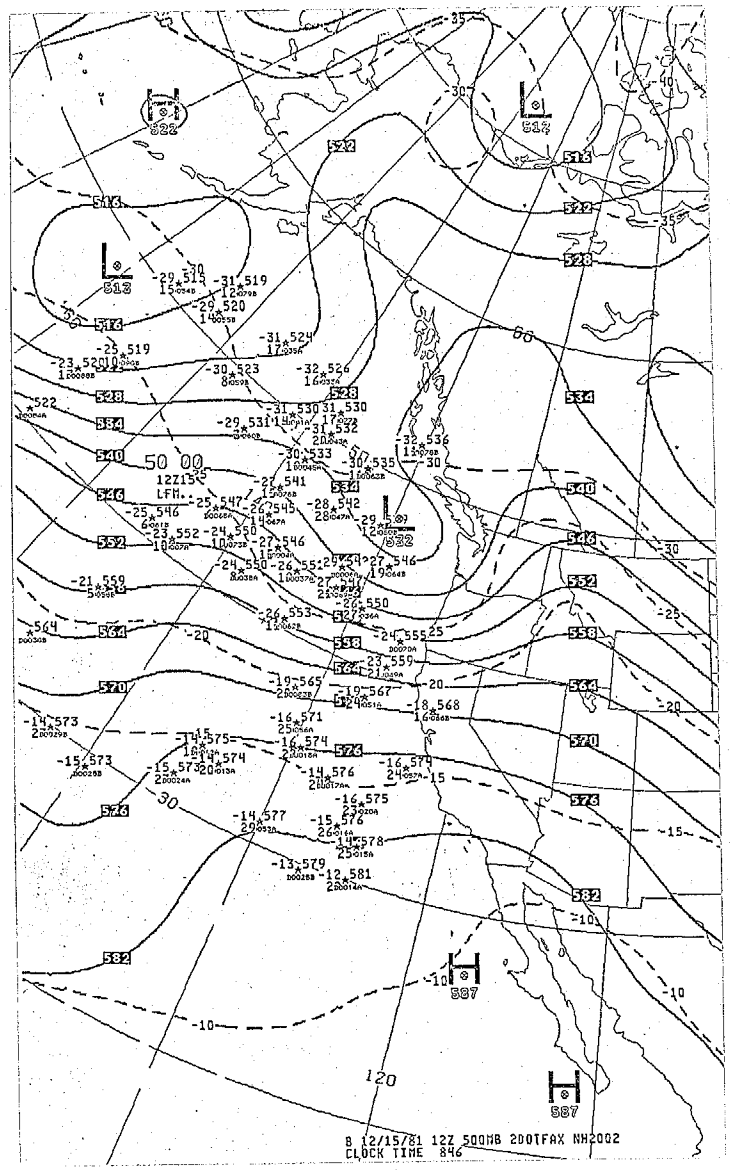


Figure 2B. 12-15-81, 12 GMT LFM 500-mb analysis with VAS data, VAS data over-plotted.

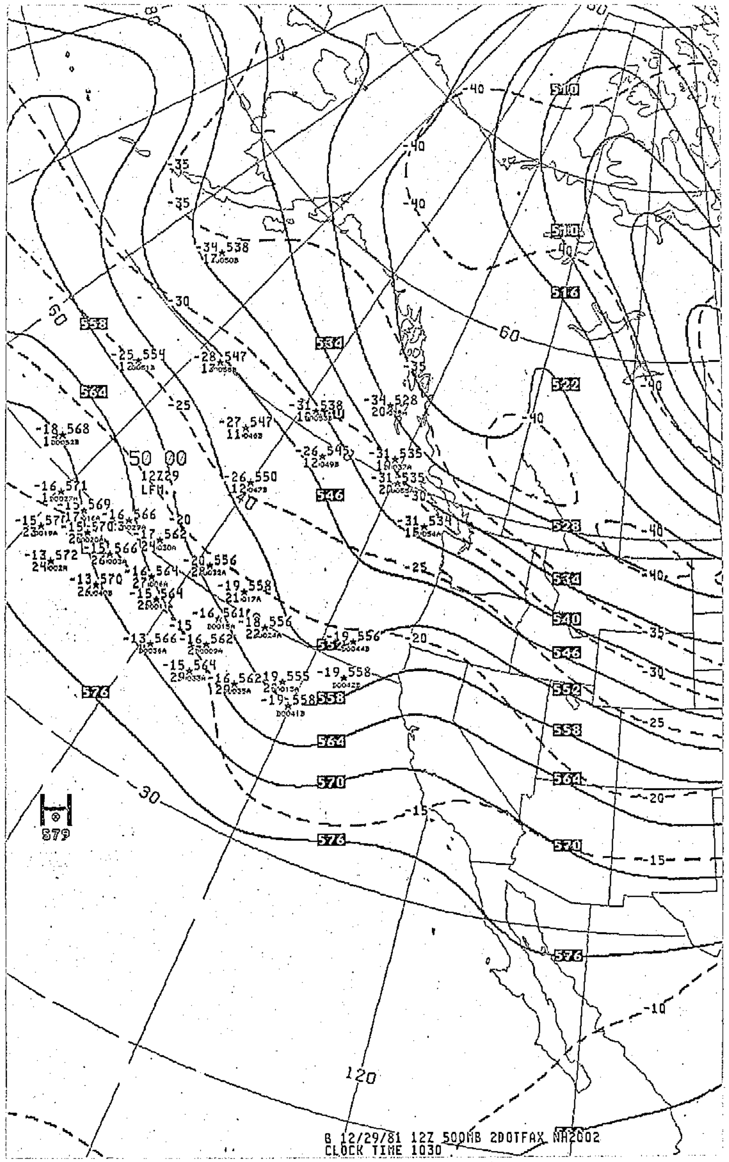


Figure 3A. 12-29-81, 12 GMT LFM 500-mb analysis with VAS data, VAS data over-plotted.

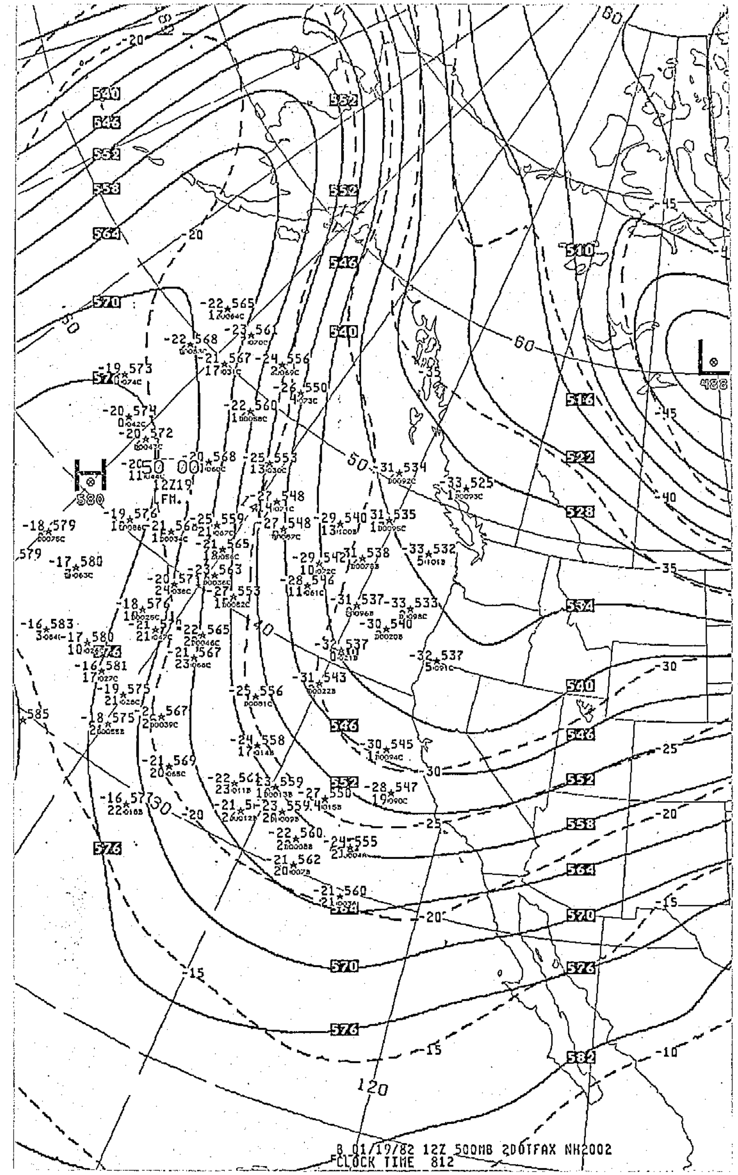


Figure 3B. 01-19-82, 12 GMT LFM 500-mb analysis with VAS data, VAS data over-plotted.

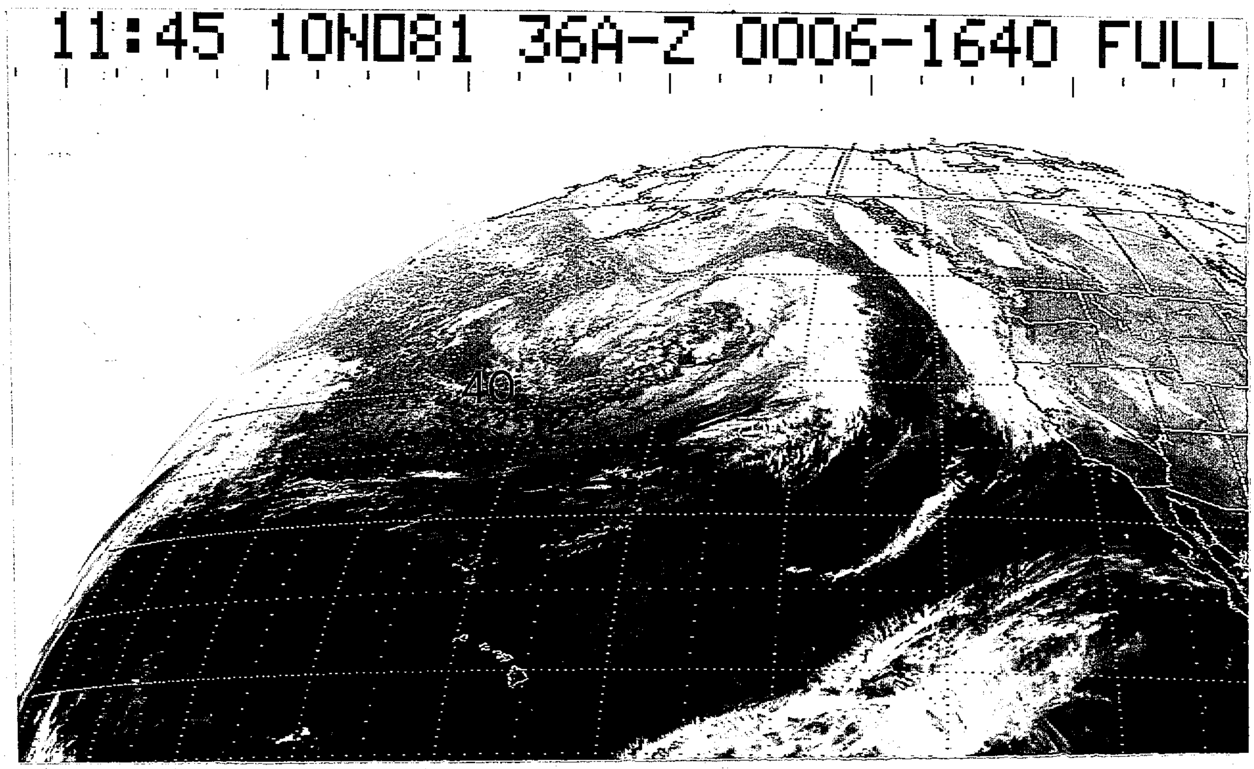


Figure 4A. Full disc infrared GOES-West satellite image, 1145 GMT 10 November 1981

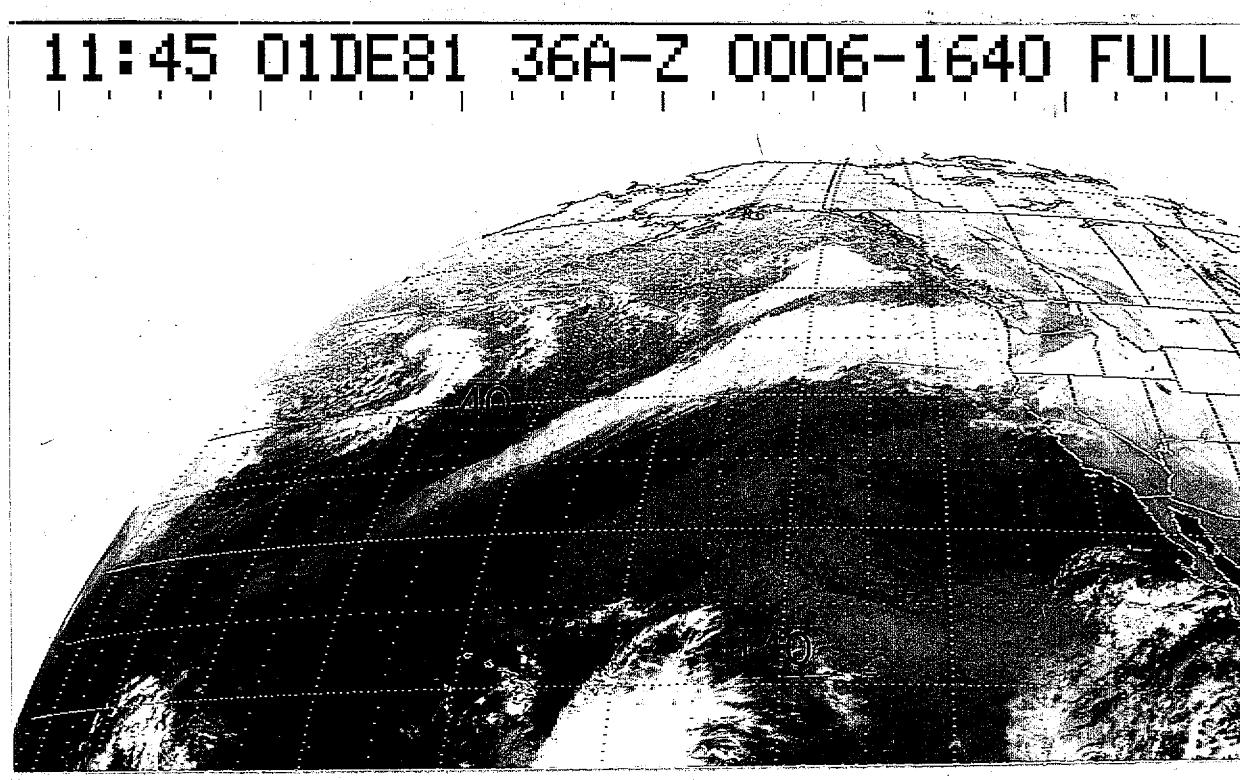


Figure 4B. Full disc infrared GOES-West satellite image, 1145 GMT 01 December 1981.

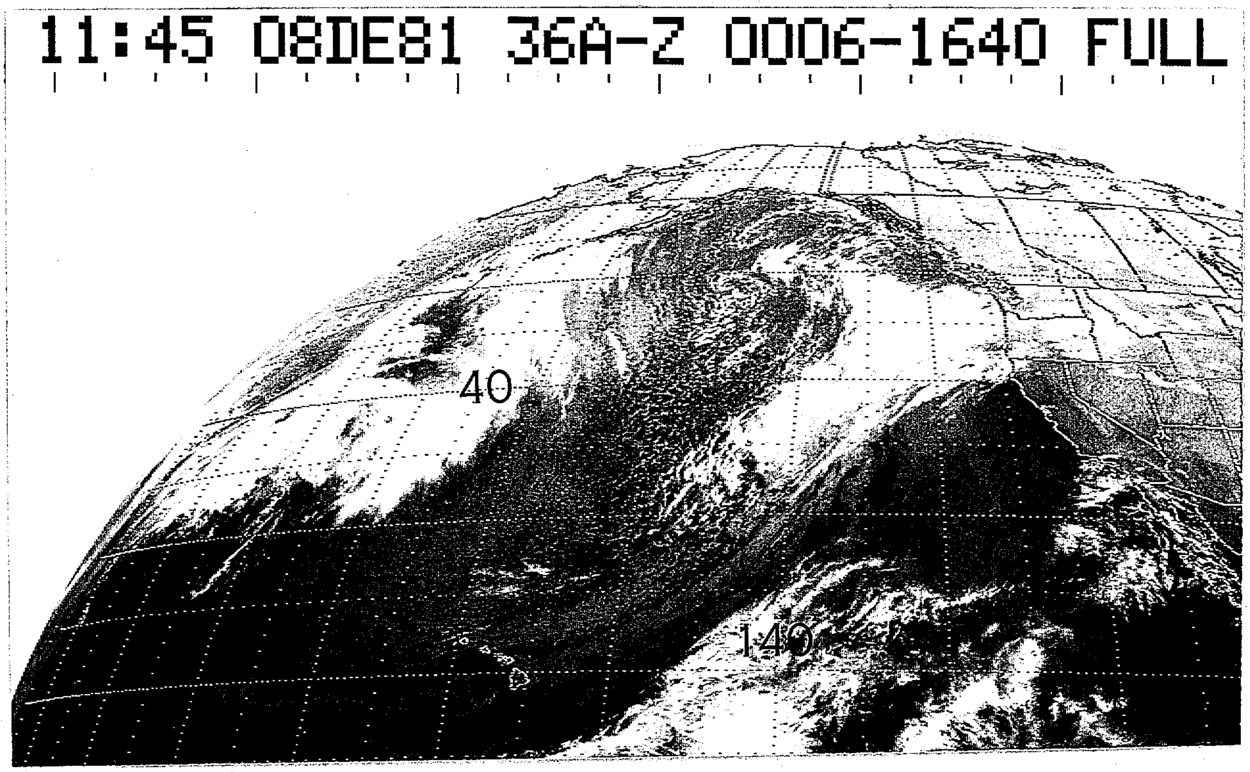


Figure 5A. Full disc infrared GOES-West satellite image, 1145 GMT 08 December 1981.

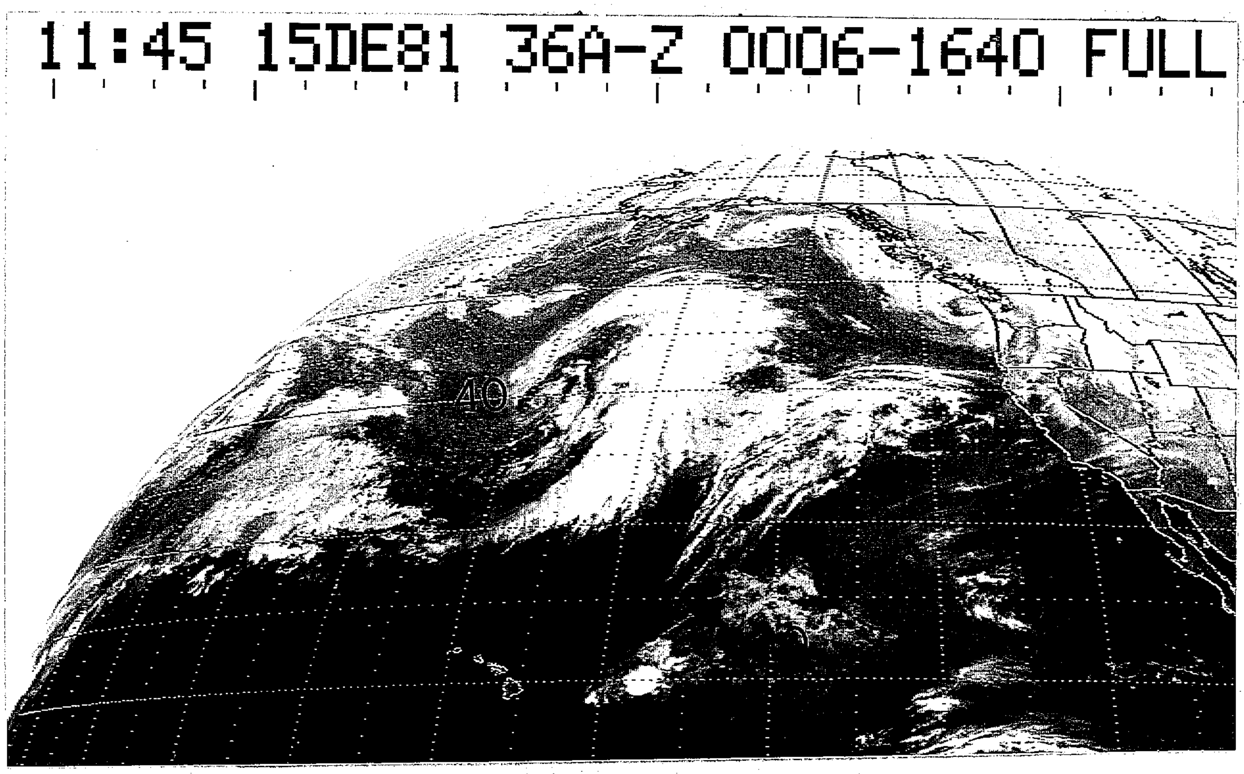


Figure 5B. Full disc infrared GOES-West satellite image, 1145 GMT 15 December 1981.

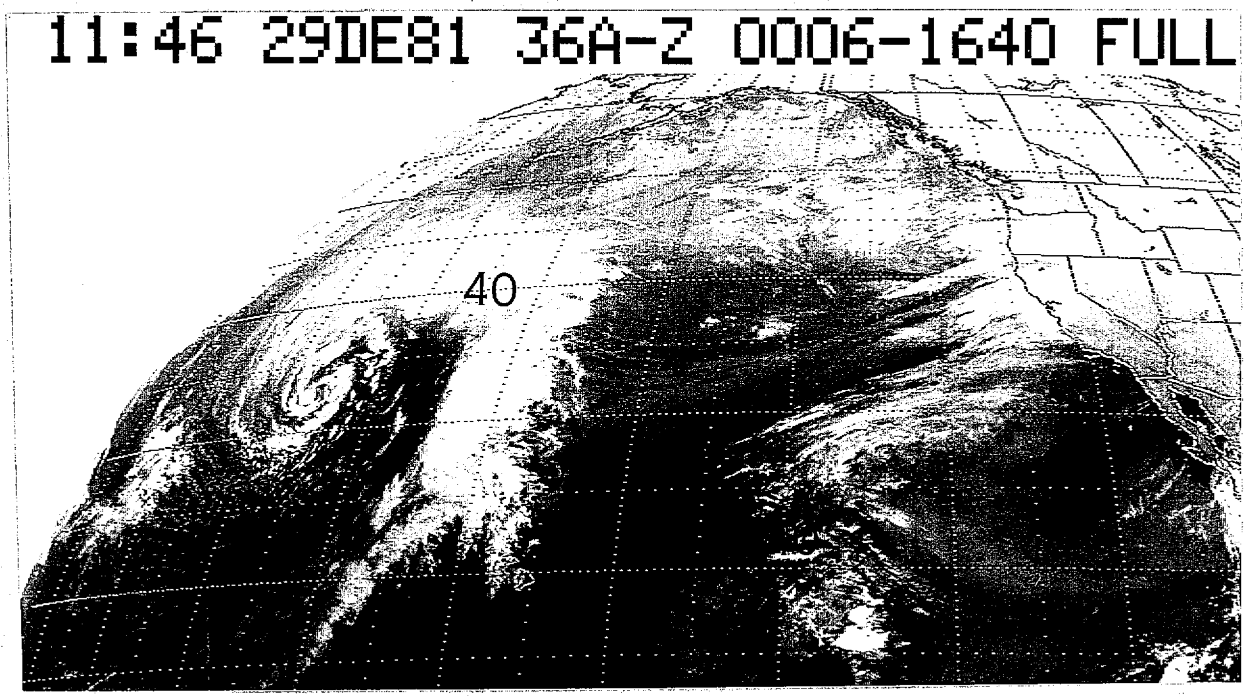


Figure 6A. Full disc infrared GOES-West satellite image, 1146 GMT 29 December 1981.

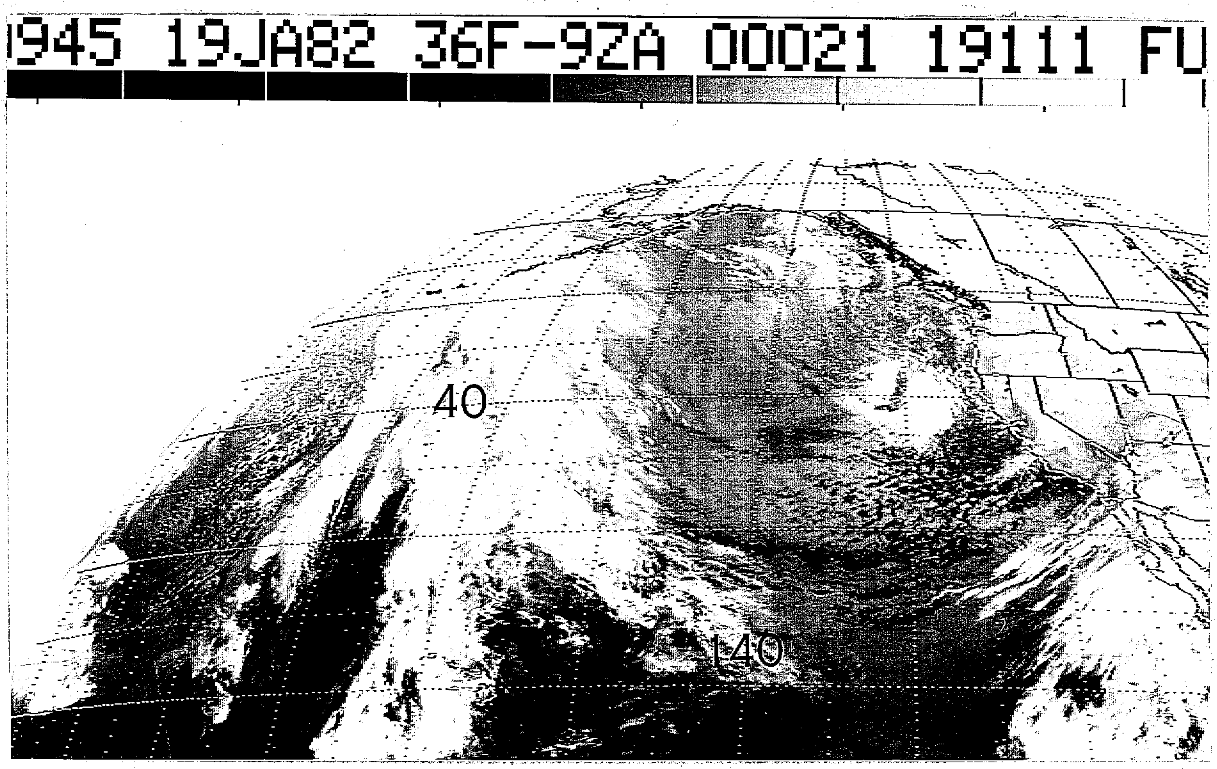


Figure 6B. Full disc infrared GOES-West satellite image, 0945 GMT 19 January 1982.

Figures 7A-F display the VAS-minus-NOVAS 500-mb height analysis differences in meters. These figures also contain the 500-mb height field contours for the NOVAS analyses (dashes), so that, by graphically adding the dashed and solid contours on these figures, one obtains the height contours for the corresponding VAS analysis.

The effect of VAS data upon the analyses varies from a marked adjustment of an apparent phase difference (Figure 7A), to the near-zero effect seen in Figure 7B. In general, the VAS-minus-NOVAS analysis differences at 500 mb appear to be negative (VAS colder), and on the order of 30 to 60 meters. At 250 mb, on the other hand, larger, positive differences (VAS warmer) appear to be the rule (Figures 8A-F). Vertical profiles of thickness-difference and layer-mean temperature difference (VAS-minus-analysis), and rms difference, averaged over all six cases (Figure 9), verify that this tendency is indeed characteristic of the six cases considered. The VAS layer-mean temperature bias is about -1.5 centigrade degrees, or about -30 meters(six case mean) for the 1000-500-mb layer. This result is similar, though smaller than that observed in a preliminary evaluation done on the two April 1981 cases (O'Lenic, 1981).

This bias need not be a fault of the retrieval method since the requirement for clear areas may introduce a systematic difference. This is because the NOVAS temperature analyses over the ocean probably differ little from the first-guess(which comes from the NMC spectral model), and a tendency to under-predict trough intensities in the spectral model, if corrected by the VAS data would produce this bias.

In order to examine the effect of the observed low-level cold bias in VAS soundings on the LFM analyses, the longitudinal variance of the 500-mb VAS and NOVAS analyses was calculated over the mesh of points shown in Figure 10. This mesh includes most, but not all of the region where VAS data were used. The results of this calculation, averaged over all six cases, are displayed in Figure 11. The VAS analyses show a lower longitudinal variance than their NOVAS counterparts by a margin of 0.1- to 0.3×10^4 meters^2 between 35°N and 44°N. North of 44°N the longitudinal variance of the VAS analyses exceeds that of the NOVAS analyses by a margin of up to 0.4×10^4 meters^2. This result probably

A. 11-10-81

B. 12-01-81

C. 12-08-81

D. 12-15-81

E. 12-29-81

F. 01-19-82

Figure 7. 500-mb VAS-minus-NOVAS LFM height analysis differences(solid lines, 30 meter intervals) with NOVAS 500-mb height analysis contours(dashed lines, 60 meter intervals).

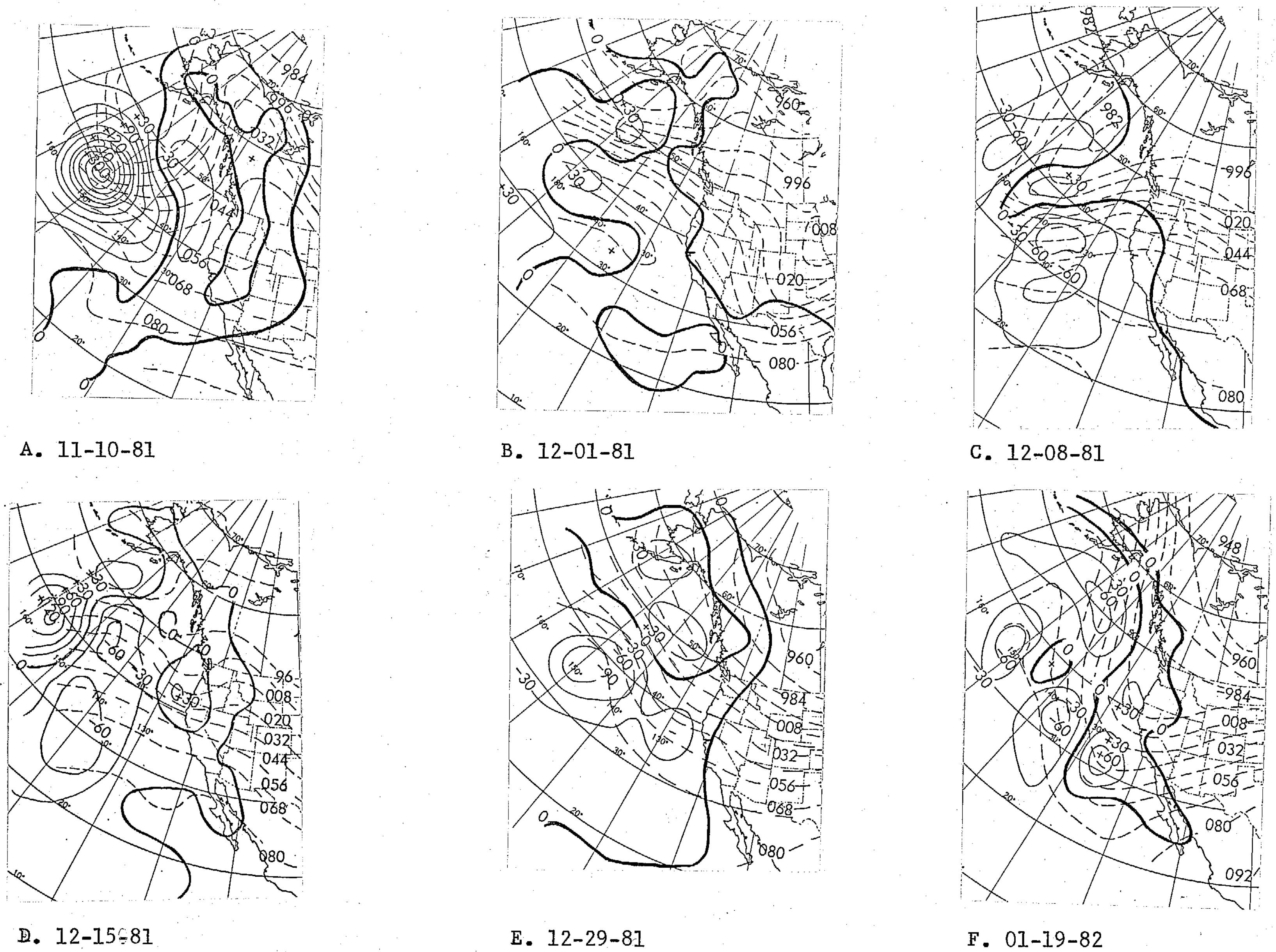


Figure 8. 250-mb VAS-minus-NOVAS LFM height analysis difference(solid lines, 30 meter intervals) with NOVAS 250-mb height analysis contours(dashed lines, 120 meter intervals).

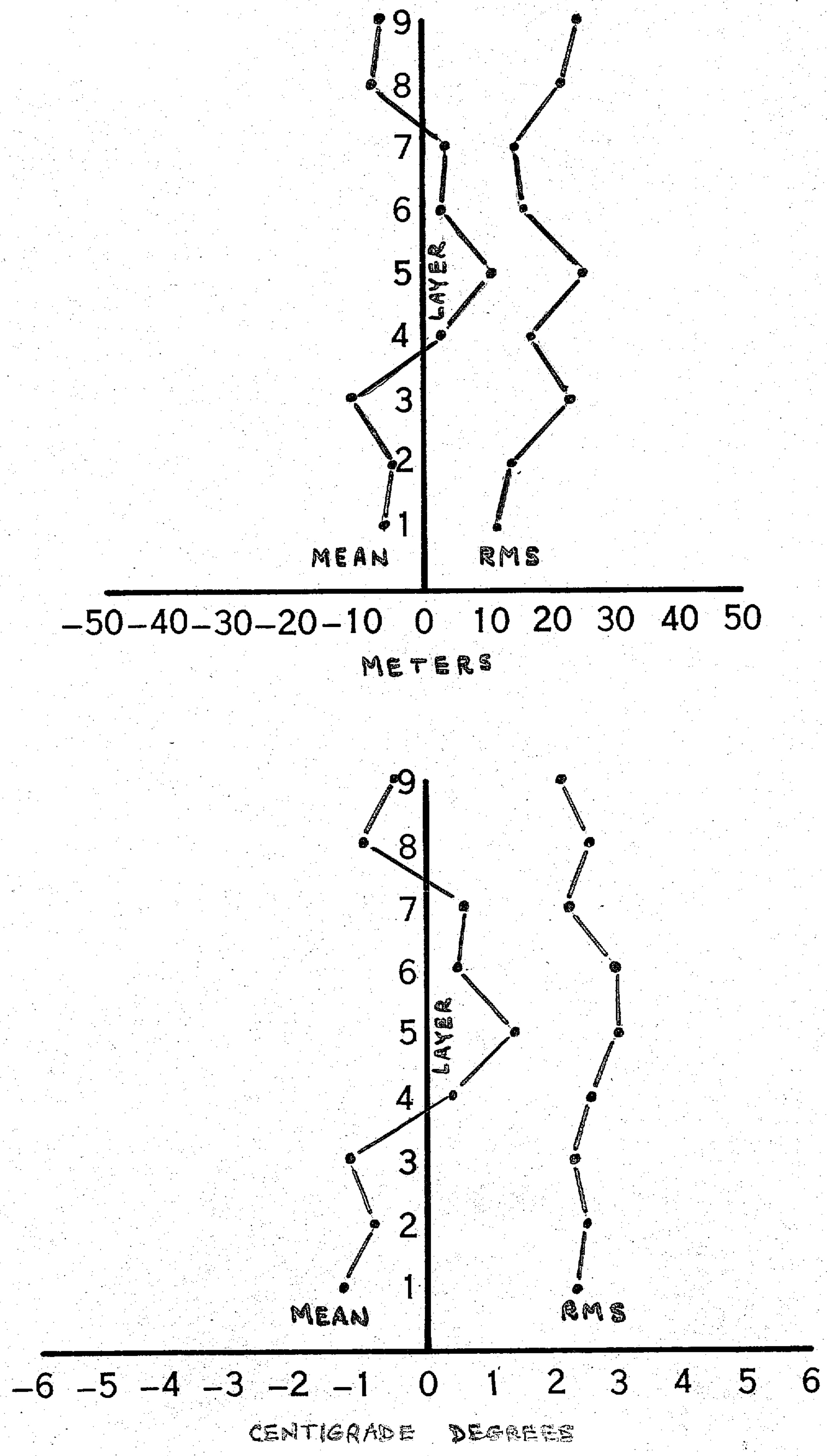


Figure 9. Standard layer thickness(meters) and mean temperature(degrees) differences, six case average; layer 1= 1000-850, layer 2= 850-700, layer 3= 700-500, layer 4= 500-400, layer 5= 400-300, layer 6= 300-250, layer 7= 250-200, layer 8= 200-150, layer 9= 150-100mb.

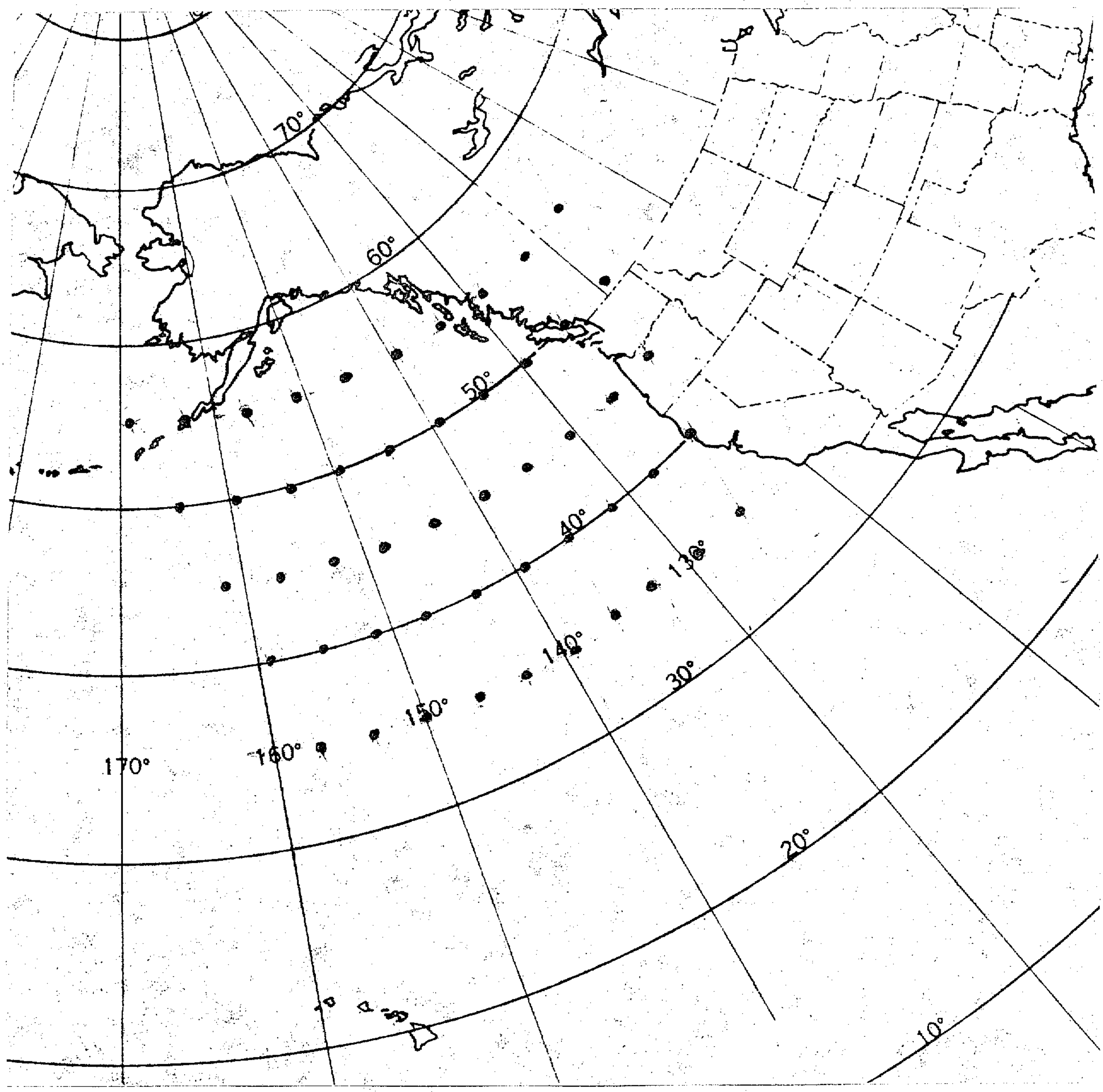


Figure 10. Points used for longitudinal height variance calculation.

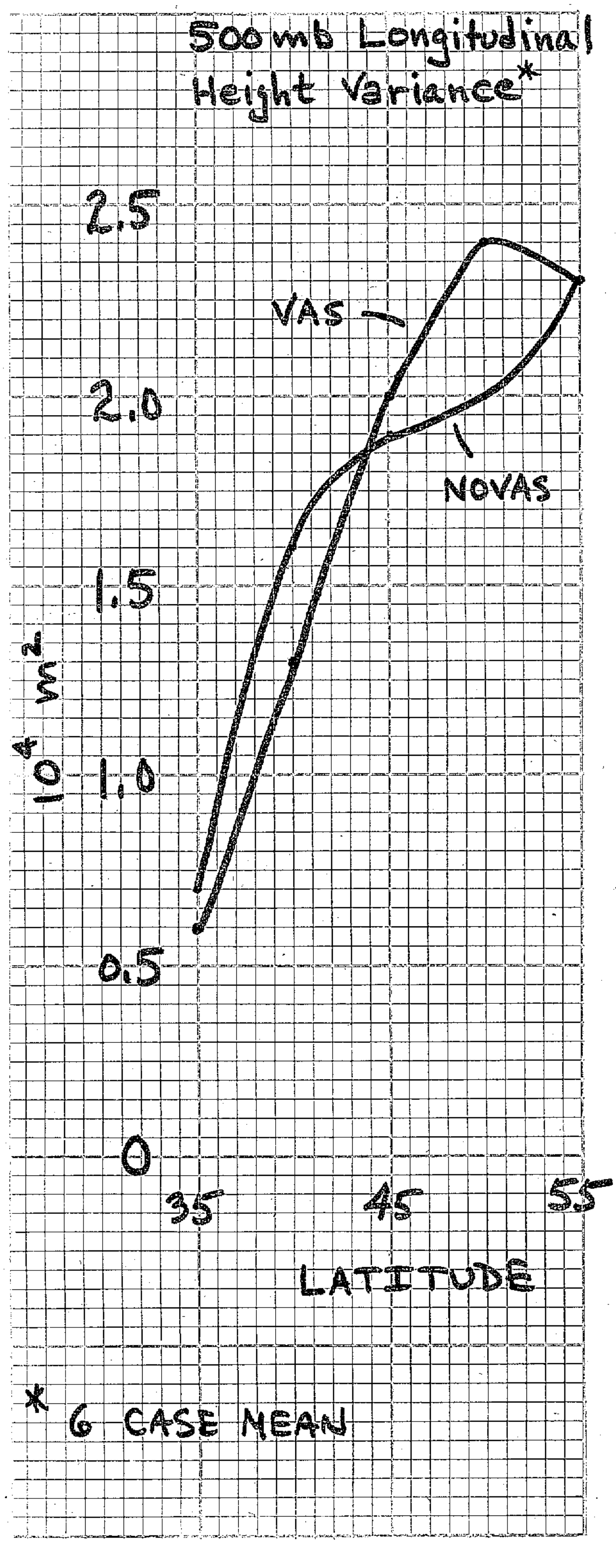
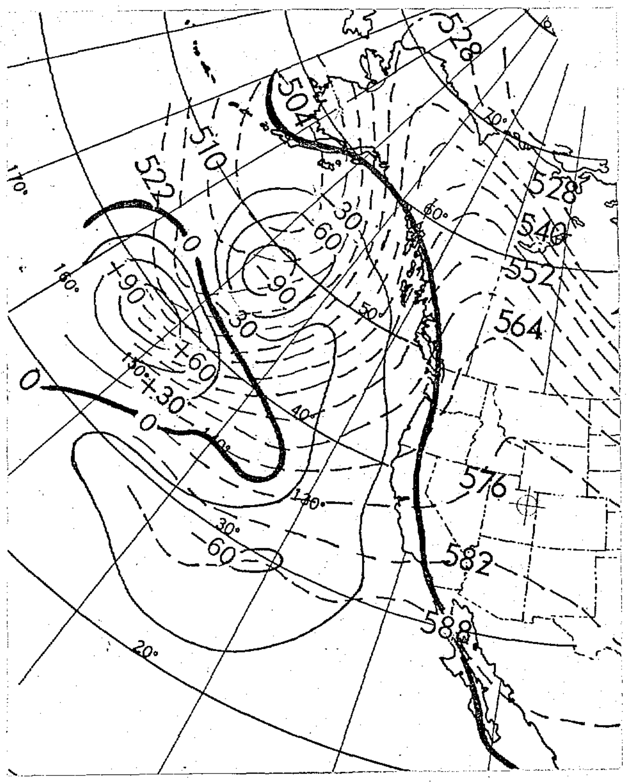


Figure 11. 500-mb longitudinal height variance, six case average, as a function of latitude, units: 10^4 meters^2 .

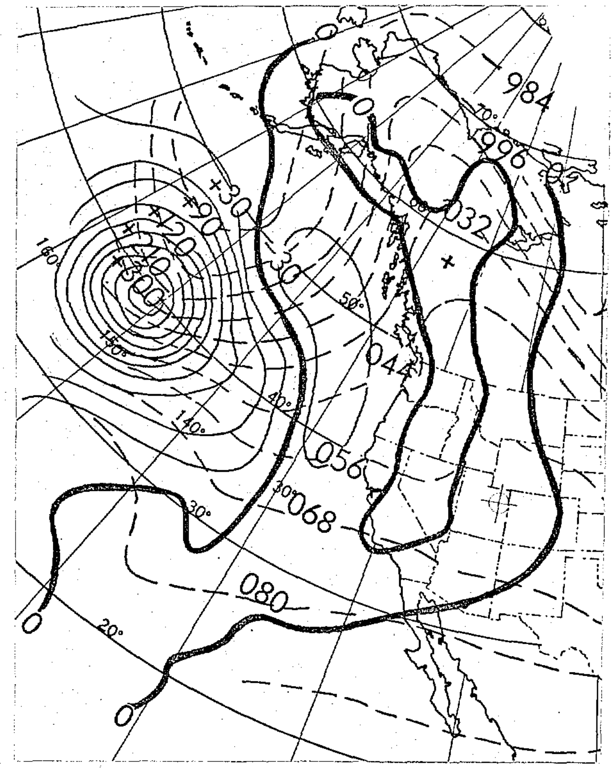
indicates that the VAS data increases the amount of information in the LFM analyses, to the north of 44°N, while it decreases the amount of information in the analyses, to the south of this latitude. This result differs from the results of such calculations in evaluations of other satellite retrieval systems (Bonner et al., 1976; Bonner et al, 1976; Desmarais et al., 1978; Miller and Hayden, 1978; Tracton et al., 1980). The findings of these studies, which evaluated NOAA-2, NOAA-2 and NIMBUS-5, NIMBUS-6, and NIMBUS-6, respectively, may be summarized by quoting from the summary and conclusions section of Desmarais et al., 1978: "Weather systems as depicted by the SAT height and thermal fields are generally weaker, i.e., have less amplitude. This reduced amplitude reflects an inherent deficiency in the remote soundings; namely, the tendency for these satellite temperature retrievals to underestimate the spatial variance in the thermal structure of the atmosphere." The results of the current study are somewhat more encouraging, at least with respect to the spatial variance of the SAT analyses.

It is instructive to compare satellite-minus-no-satellite (SAT-minus-NOSAT) analysis differences for two satellite observing systems: VAS and NOAA-7, for the 11-10-81 case (Figures 12 A-D). VAS and NOAA-7 produce very similar 500-mb height difference patterns (Figures 12 A,C). Both tend to "correct" the phasing of the trough in the NOSAT analysis, by shifting its northern portion eastward. The VAS "correction" decreases heights everywhere within the trough and along 130°W by about thirty meters more than its NOAA-7 counterpart, while NOAA-7 produces larger height rises near 155°W. At 250 mb the amplitude of the VAS differences (Figure 12B) is about sixty meters larger than those for NOAA-7 (Figure 12 D).

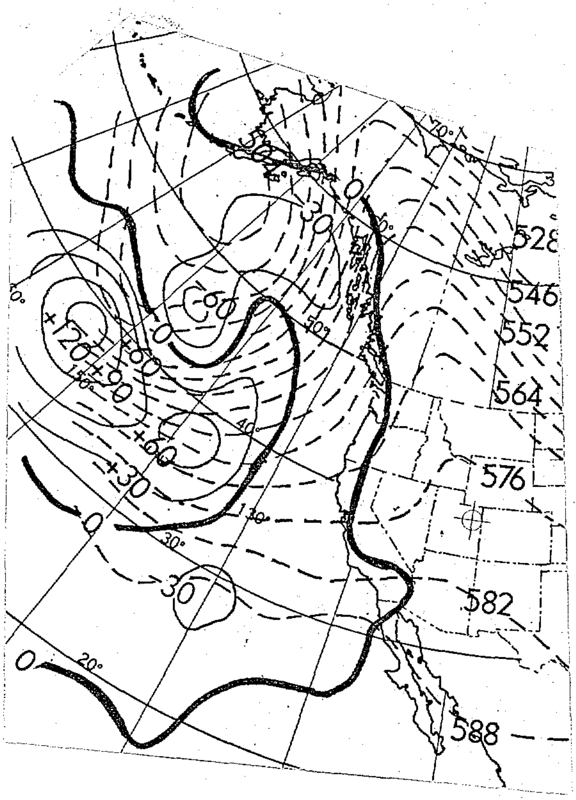
While such a limited comparison between VAS and NOAA-7 satisfies us that the two observing systems produce observations which agree in general, we still cannot be certain of the accuracy of either system, due to the lack of truth data in the vicinity of the satellite observations. The most practical measure of the usefulness of analyses made using satellite data are forecasts produced using those analyses. The next section examines a set of such forecasts.



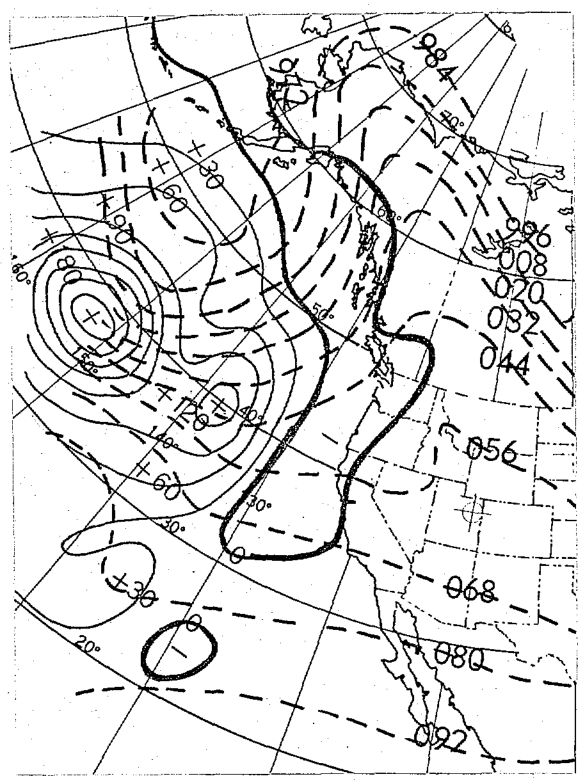
A. 500-mb VAS-minus-NOVAS



B. 250-mb VAS-minus-NOVAS



C. 500-mb NOAA-7-minusNO-NOAA-7



D. 250-mb NOAA-7-minus-NO-NOAA-7

Figure 12. SAT-minus-NOSAT LFM height analysis differences(solid lines, 30 meter intervals) with NOSAT analysis contours(dashed lines, intervals of 60 meters at 500-mb, and 120 meters at 250-mb) for 11-10-81 case.

3. VAS and NOVAS forecast comparisons

This section compares LFM forecasts out to 48 hours, prepared using the VAS analyses(VAS-forecasts), with those forecasts made using only conventional data (NOVAS-forecasts, these are also the NMC operational LFM forecasts). Mr. Ralph Jones used the operational version of the LFM ten-layer model (Gerrity, 1976; Newell et al., 1981) to produce the VAS-forecasts. 500-mb height differences (forecast-minus-observed, or F-O) were computed for the 24- and 48-hour VAS and NOVAS forecasts. These difference fields, displayed in Figures 13-18, contain both the 500-mb height difference(F-O) contours (solid lines) in 60-meter intervals, and the 500-mb height contours for the verifying analysis (dashed lines). Thus, adding the solid error contours to the dashed analysis contours yields the contours of the VAS-forecast 500-mb height field.

A. 11-10-81

This case, which exhibited the largest VAS-minus-NOVAS analysis differences (Figures 7A,8A), also shows a very large VAS-induced effect upon the 500-mb height forecasts. At 24-hours (Figures 13A,C), the VAS forecast already shows a 60-meter improvement, as the information from the VAS analysis is advected eastward approximately at the speed of the wind. By 48-hours (Figures 13B, D), this improvement increases to about 90-meters over the western USA. Note also the reduction of the positive error over the northern portion of Canada as the information from the analysis continues moving northeastward.

B. The 12-01-81 case

VAS data produced a near-zero change in the height analyses (Figures 7B, 8B) for this case, and, as can be observed in Figures 14A-D, there was no significant effect upon the mediocre forecast.

C. The 12-08-81 case

The large (up to 60-meters, or more) change in the analysis wrought by VAS data (Figures 7C, 8C) translate into an improvement in the 48-hour forecast of like magnitude (Figures 15A-D). Again, the improvement is limited to the region where we would expect the information to be, based on the flow pattern.

D. The 12-15-81 case

The really quite substantial analysis changes induced by VAS (Figures 7D, 8D) have little or no effect upon a poor forecast (Figures 16A-D).

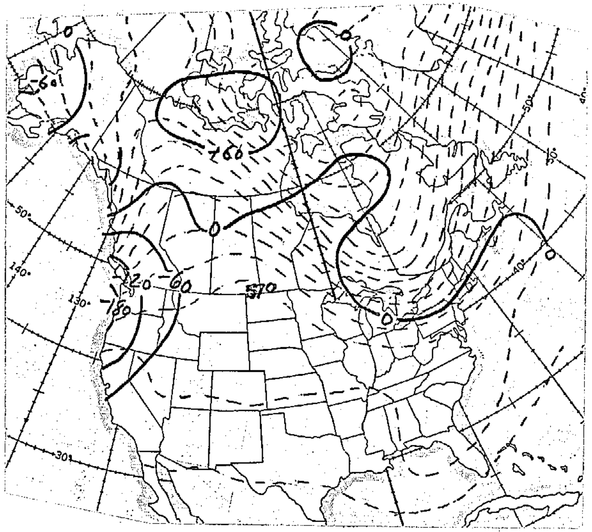


Figure 13A. NOVAS 500-mb height errors (solid lines) for 24-hour LFM forecast valid 12 GMT, 11-11-81. Verifying 500-mb analysis contours are dashed at 60-meter intervals.

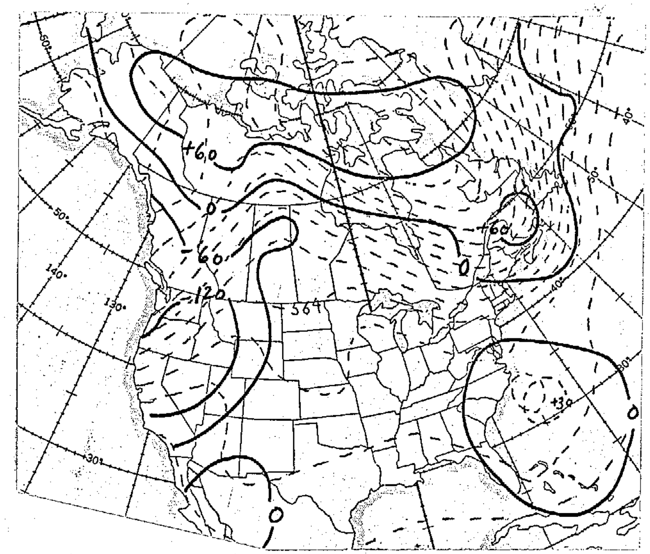


Figure 13B. NOVAS 500-mb height errors (solid lines) for 48-hour LFM forecast valid 12 GMT, 11-12-81. Verifying 500-mb analysis contours are dashed at 60-meter intervals.

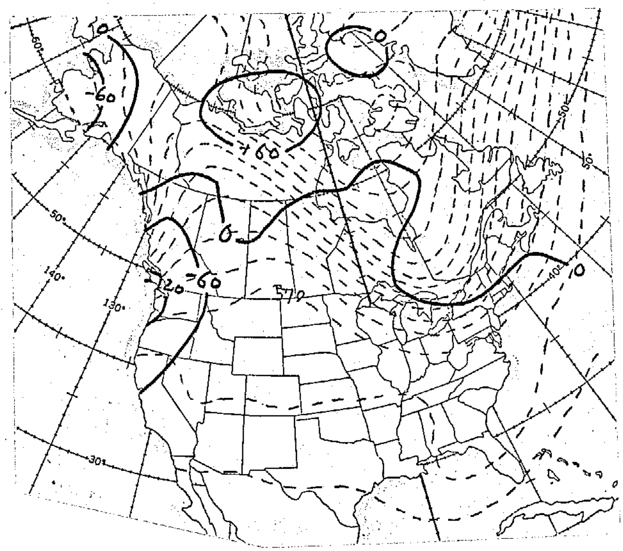


Figure 13C. VAS 500-mb height errors (solid lines) for 24-hour LFM forecast valid 12 GMT, 11-11-82. Verifying 500-mb analysis contours are dashed at 60-meter intervals.

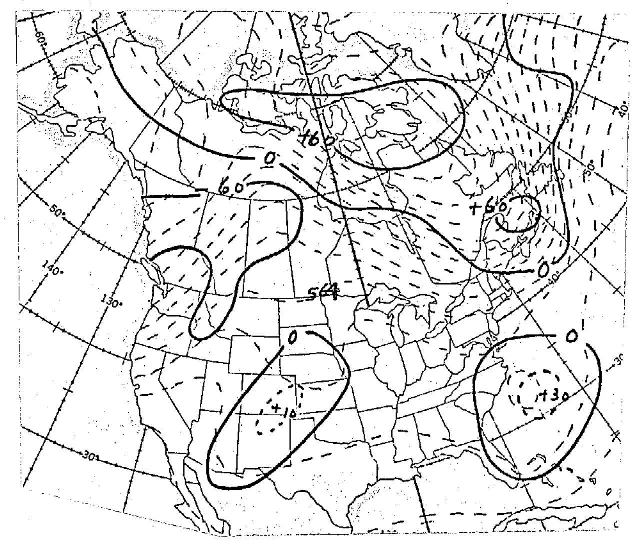


Figure 13D. VAS 500-mb height errors(solid lines) for 48-hour LFM forecast valid 12 GMT 11-12-81. Verifying 500-mb analysis contours are dashed at 60-meter intervals.

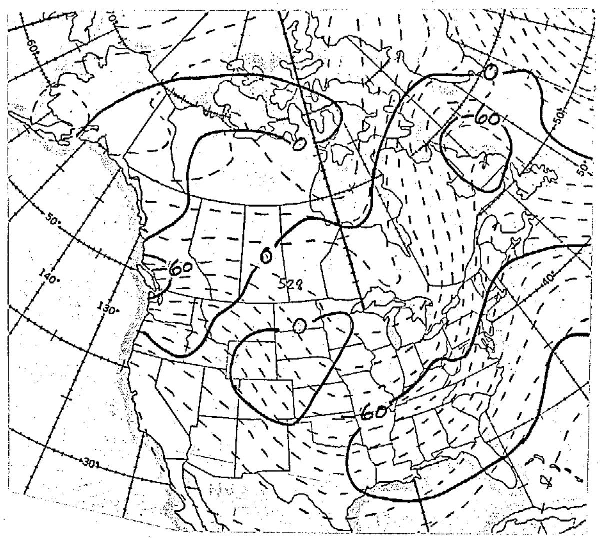


Figure 14A. Same as Figure 13A, except for 12-02-81.

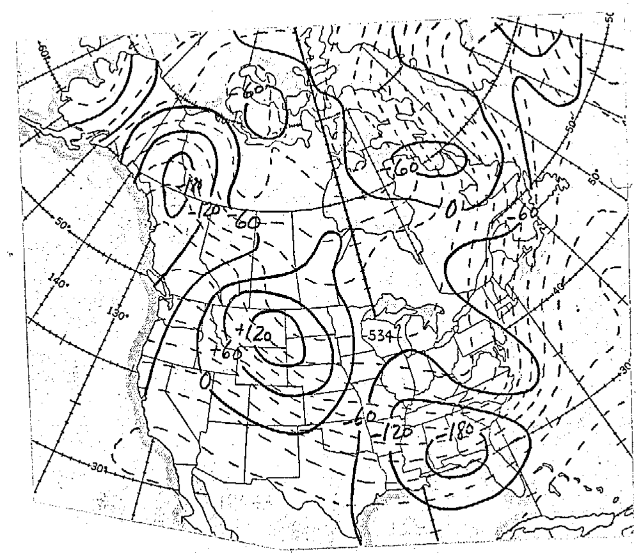


Figure 14B. Same as Figure 13B, except for 12-03-81.

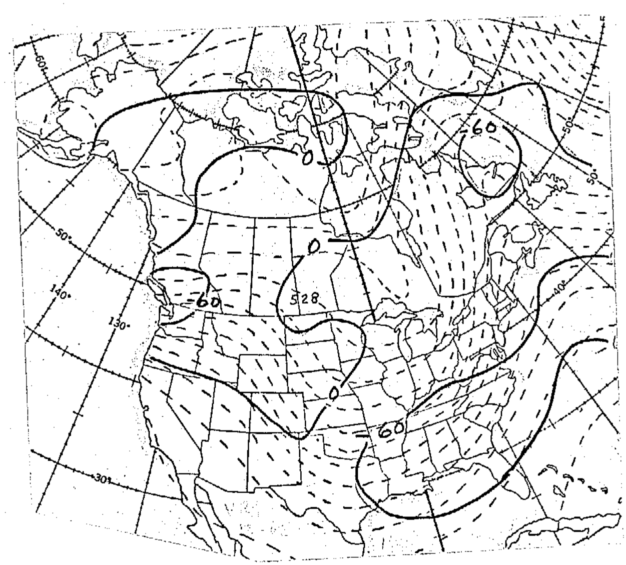


Figure 14C. Same as Figure 13C, except for 12-02-81.

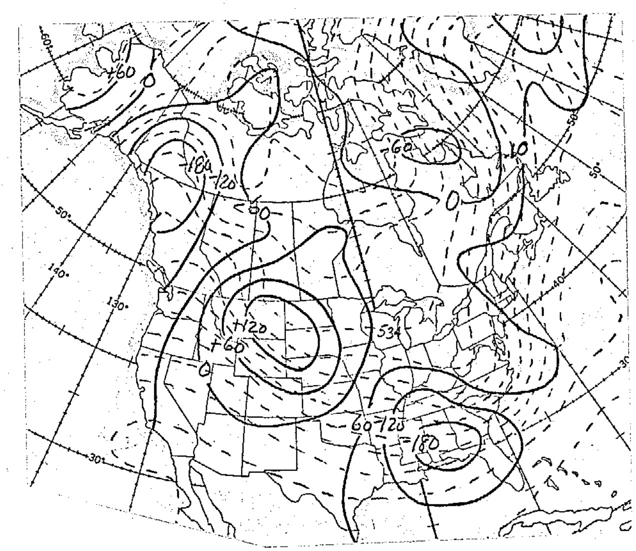


Figure 14D. Same as Figure 13D, except for 12-03-81.

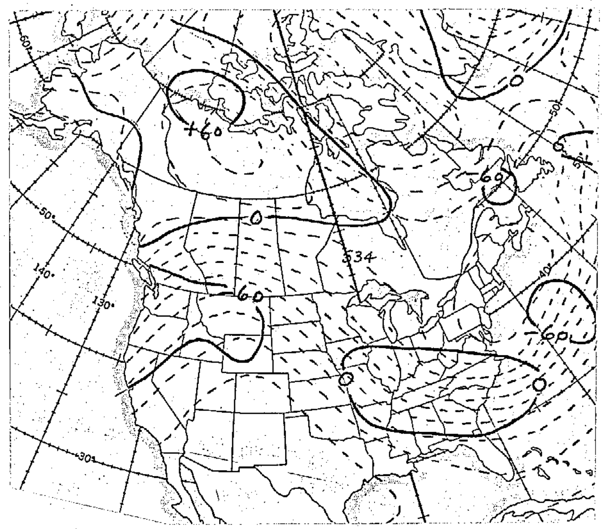


Figure 15A. Same as Figure 13A, except for 12-09-81.

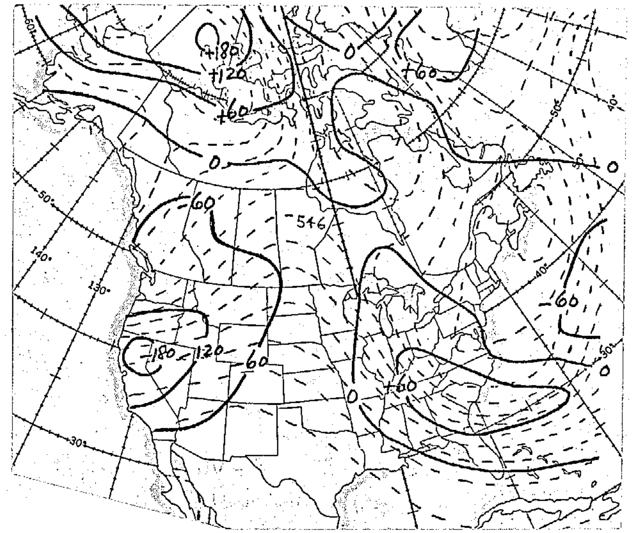


Figure 15B. Same as Figure 13B, except for 12-10-81.

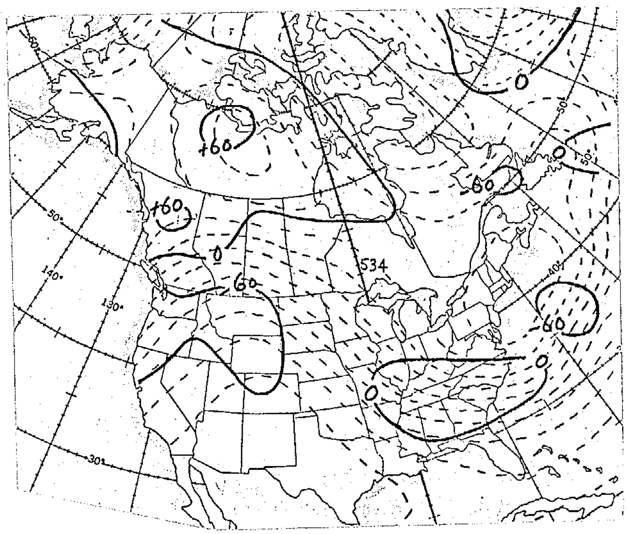


Figure 15C. Same as Figure 13C, except for 12-09-81.

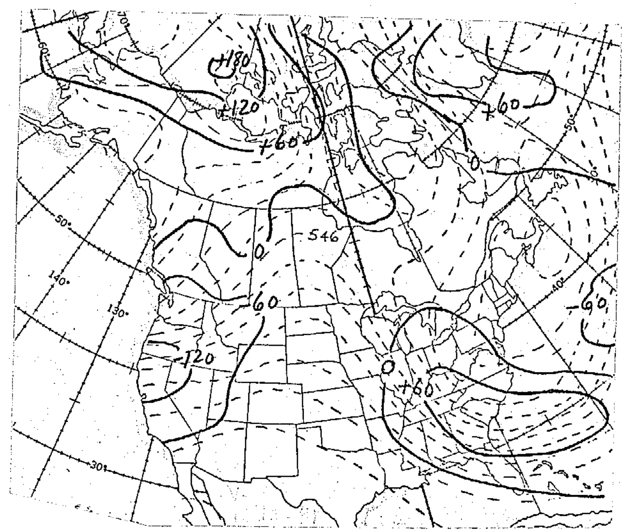


Figure 15D. Same as Figure 13D, except for 12-10-81.

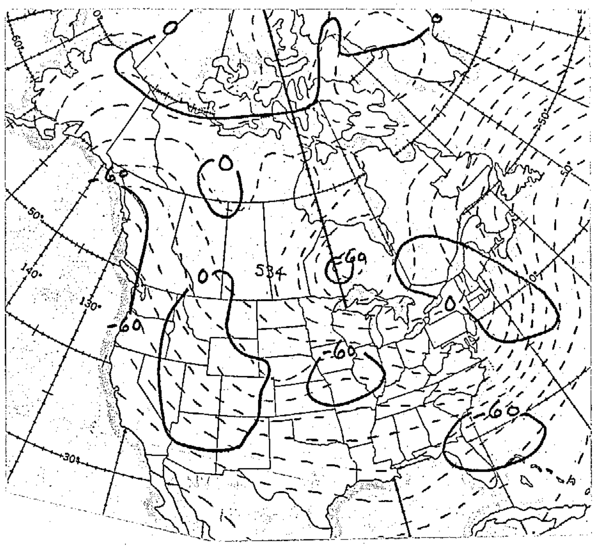


Figure 16A. Same as Figure 13A, except for 12-16-81.

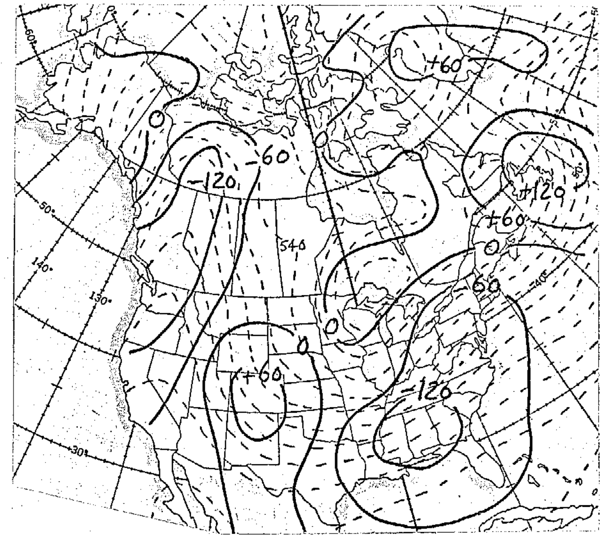


Figure 16B. Same as Figure 13B, except for 12-17-81.

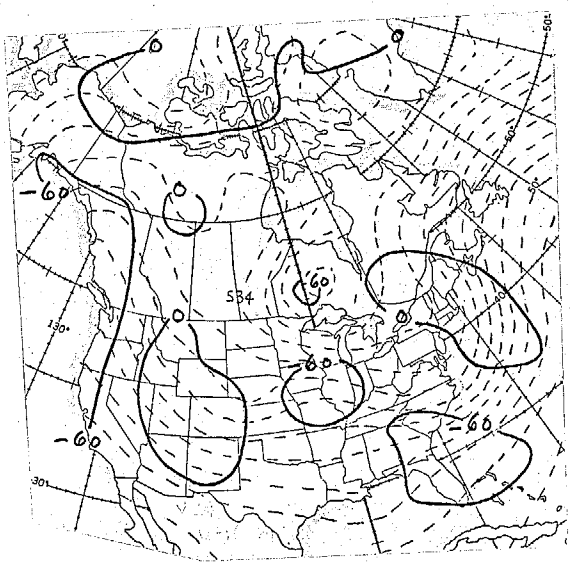


Figure 16C. Same as Figure 13C, except for 12-16-81.

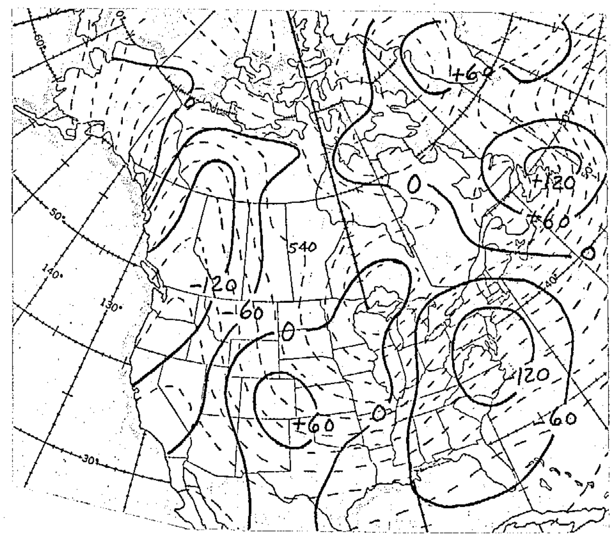


Figure 16D. Same as Figure 13D, except for 12-17-81.

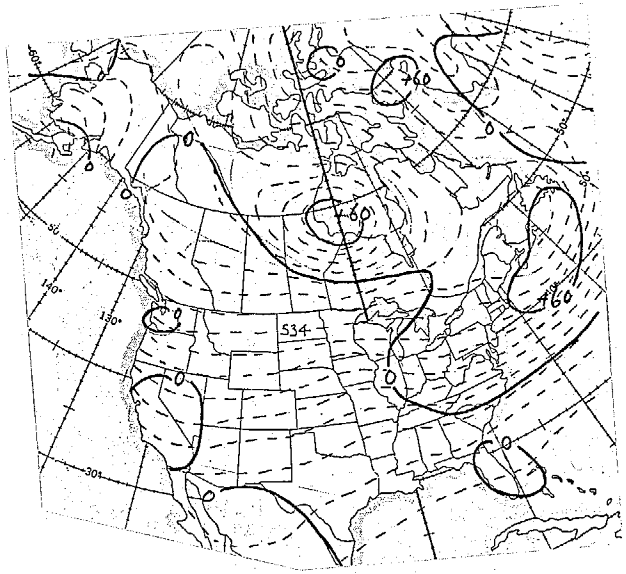


Figure 17A. Same as Figure 13A, except for 12-30-81.

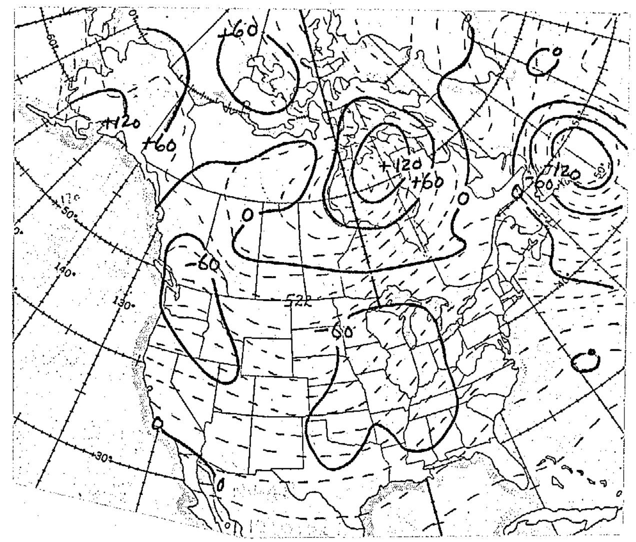


Figure 17B. Same as Figure 13B, except for 12-31-81.

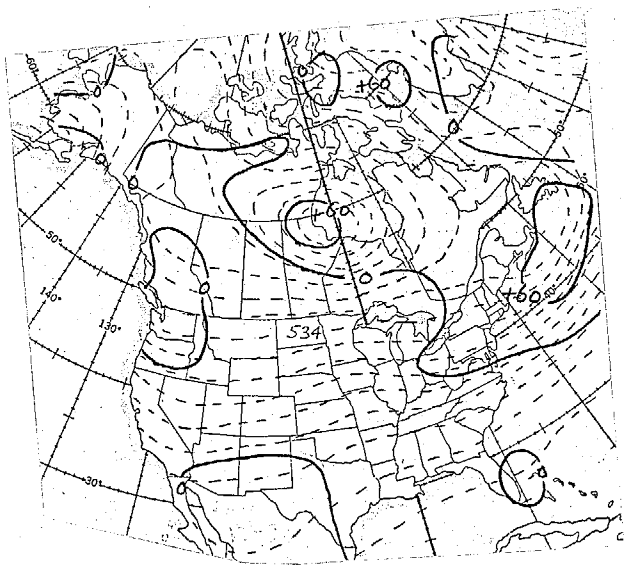


Figure 17C. Same as Figure 13C, except for 12-30-81.

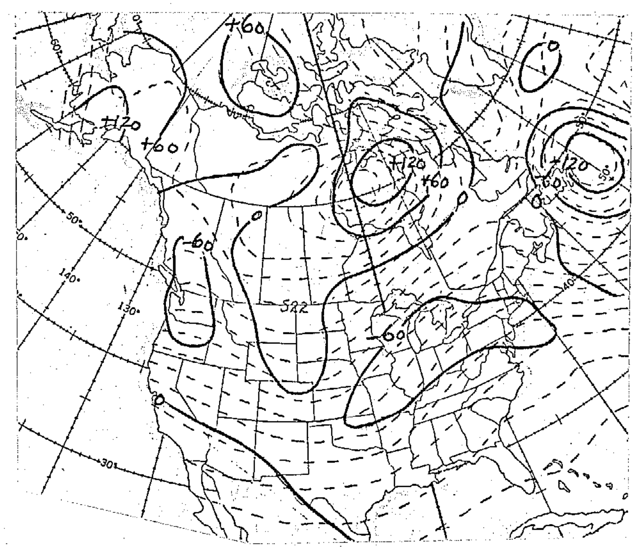


Figure 17D. Same as Figure 13D, except for 12-31-81.

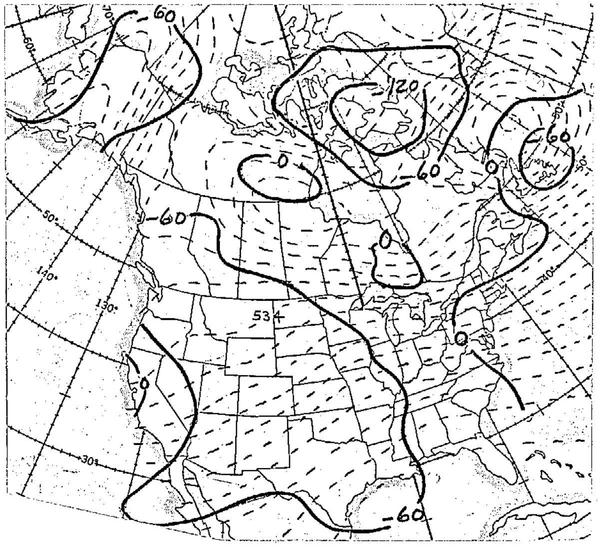


Figure 18A. Same as Figure 13A, except for 01-20-82.

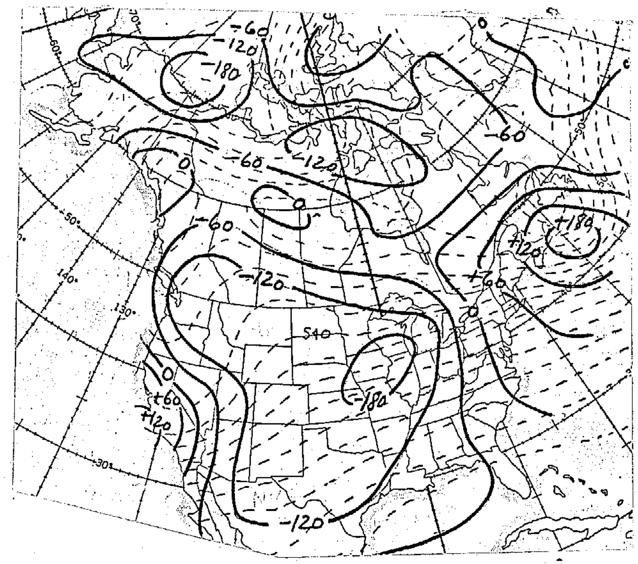


Figure 18B. Same as Figure 13B, except for 01-21-82.

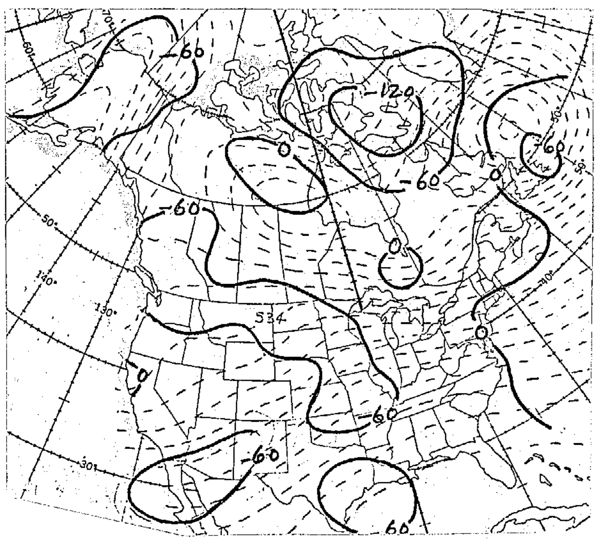


Figure 18C. Same as Figure 13C, except for 01-20-82.

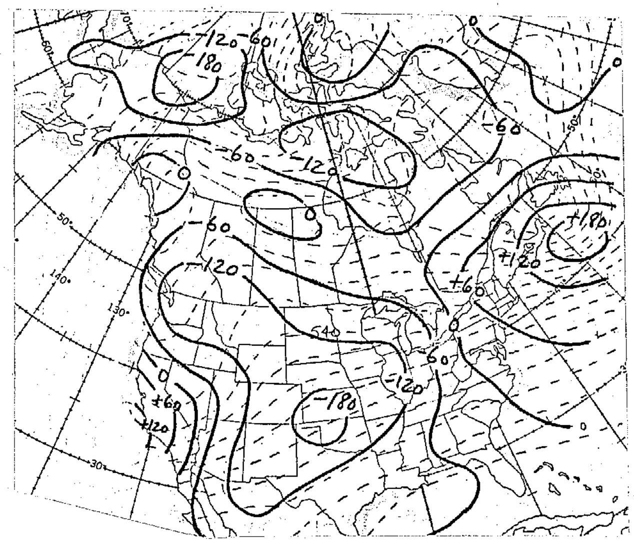


Figure 18D. Same as Figure 13D, except 01-21-82.

E. The 12-29-81 case

This case is difficult to classify. The VAS data produced very large and complex changes in the analysis (Figures 7E, 8E), breaking down the ridge near 150°W, at 250 mb, but not at 500 mb, and deepening the trough near 130°W at 500 mb, but not at 250 mb. But, the VAS forecast shows no improvement to an already satisfactory forecast (Figures 17A-D).

F. The 01-19-82 case

The VAS-minus-NOVAS analysis differences for this case (Figures 7F,8F) indicate that the VAS data "corrected" some fairly substantial (60+ meters at 250 mb, and 30+ meters at 500 mb) analysis differences, both in the phase and the amplitude of the large trough along 130°W. The VAS analysis very slightly improves the 24-hour forecast over the western USA (Figure 18C). However, by 48-hours (Figure 18D), even though we can still see some improvement, i.e., the reduced area enclosed by the −120m contour, whatever is degrading the forecast everywhere else, negates any possible claim to improvement, as can be seen from the error pattern along the southern California coast, where there is little difference between the VAS and NOVAS forecasts at 48-hours.

4. Summary, Conclusions, Recommendations

This paper has examined the effect of VAS data upon a set of six LFM analyses and forecasts made during the fall and winter of 1981-1982. At 500 mb, the VAS analyses exhibited a considerable (30 to 60 meter) difference from NOVAS analyses. VAS soundings are, on average, colder in the 1000-500-mb layer by up to 1.5 centigrade degrees, and warmer by about the same margin between 500 and 200 mb, than the original LFM analyses. The longitudinal variance of the 500-mb analyses is less than those without VAS, to the south of 44°N, but is larger, by up to $0.4 \times 10^4 m^2$, to the north of this latitude. A comparison of VAS and NOAA-7 analyses was made for one case in which a large phase difference was observed between the SAT (VAS and NOAA-7) and the NOSAT analyses. The NOAA-7 analysis reproduced the essential, high-amplitude features of the VAS analysis, though the NOAA-7 analysis differences exhibited somewhat higher amplitude at 500 mb, and lower amplitude at 250 mb, than their VAS counterparts. Two out of six of the VAS-forecasts were improved by from 60-to 90-meters at 500 mb over the NOVAS forecasts. In one case, VAS data introduced large and complex changes to the NOVAS analysis, yet the VAS-forecast showed little significant improvement to a forecast, which in the NOVAS mode was already satisfactory. There were two cases in which VAS did little to improve poor forecasts, and one, in which the small observed improvement was far overshadowed by the low quality of the forecast. In summary, using VAS data improved two of the six forecasts studied, and, while the remaining VAS-forecasts showed little significant improvement, neither did any forecasts exhibit reduced accuracy.

The analysis method used for the LFM system(Cressman,1959) has been used operationally at NMC for twenty-four years. It has the feature that independent analyses are made first at 1000 and 300 mb. In the absence of data between these levels, the temperature lapse rate in the first guess is preserved in the analysis. When a 1000-mb report (e.g. a surface ship) deepens a trough or low center, and there is no other data, the typical result is the appearance of excessively warm temperatures at low levels in the analysis above the area of lowered 1000-mb heights. This is because, under the stated conditions, the analysis reduces the effect of such a height change from a maximum value at 1000 mb to a zero change at 300 mb. A 1000-300 bias of opposite sign would be expected when a 1000-mb ridge or high center is amplified by surface ship data. Lows generally have more concentrated centers than highs, however, and are more likely to require correction of the first guess by surface data. This will lead to the falsely-analysed lower tropospheric described above. Such a bias might not occur in another, truly 3-dimensional analysis system. If the VAS thicknesses were identical to those in the first-guess, the 1000-mb height change described would be transmitted <u>undiminished</u> with height, upward throughout the atmospheric column, and would correct the excessively warm (or cold) thicknesses back to the first-guess thicknesses, producing a marked reflection of 1000-mb features at all levels up to and including 300 mb. The effect of this process would be to produce either an apparent cold, or warm bias, respectively, even though the VAS temperatures agreed with the first-guess. It is therefore suggested that further test with VAS data use an up-to-date three-dimensional analysis system in order to eliminate such complications.

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